



Questionable devices: Applying a large language model to deliberate carbon removal

Dr. Laurie Waller^{a,*}, Dr. David Moats^{b,2}, Dr. Emily Cox^{c,3}, Dr. Rob Bellamy^{d,4}

^a Department of Geography, University of Manchester, Manchester, UK

^b Centre for Consumer Society Research, University of Helsinki, Helsinki, Finland

^c Smith School of Enterprise and the Environment, University of Oxford, Oxford, UK

^d Department of Geography, University of Manchester, Manchester, UK

ARTICLE INFO

Keywords:

Carbon removal

Deliberation

Devices

Publics

Experiments in participation

Large language models

Generative AI

ABSTRACT

This paper presents a device-centred approach to deliberation, developed in deliberative workshops appraising methods for removing carbon dioxide from the air. Our approach involved deploying the Large Language Model application ChatGPT (sometimes termed “generative AI”) to elicit questions and generate texts about carbon removal. We develop the notion of the “questionable” device to foreground the informational unruliness ChatGPT introduced into the deliberations. The analysis highlights occasions where the deliberative apparatus became a focus of collective critique, including over: issue definitions, expert-curated resources, lay identities and social classifications. However, in this set-up ChatGPT was all too often engaged unquestioningly as an instrument for informing discussion; its instrumental lure disguising the unruliness it introduced into the workshops. In concluding, we elaborate the notion of questionable devices and reflect on the way carbon removal has been “devised” as a field in want of informed deliberation.

1. Introduction

“Magic Mirror on the wall...”. As is well known, the Evil Queen in *Snow White* uses the magic mirror very instrumentally, posing a question – “who is the fairest of them all?” – to reassure herself of her status in the monarchical social order. Enchanted by the mirror’s initially flattering responses, the Queen is lured into a narcissistic deliberation. The policy of extermination she arrives at (kill Snow White) is blind to the realities of power in the kingdom: the Queen’s bungled attempts to implement the policy leading to her downfall. This magic mirror can answer questions, but a mirror also has the capacity to reflect back onto the questioner and the wider situation: would the Queen have proven so Evil had she questioned the mirror in other, less instrumental, ways?

Public deliberation procedures often enact strong distinctions

between explicitly normative questions (of the kind posed by the Queen) and technical questions, such as: “What is the feasibility of carbon removal and over what timeframe?”.¹ In deliberative procedures, questions of the latter type are often addressed to experts as requests for information, while the former are located in the domain of public discussion. However, it has long been observed that, in practice, ostensibly technical questions often disguise normative commitments and can leave scientific “framings” of the public unquestioned (Wynne, 2016). For example, questions about the feasibility of carbon removal can “frame out” political contestation over its place in struggles against climate change (Waller et al., 2020). In this paper, we attend not only to how deliberative procedures frame questions and questioning subjects, but also to the *devices* that – like the magic mirror – elicit questioning and participate in performances of deliberation.

* Corresponding author.

E-mail addresses: laurie.waller@manchester.ac.uk (Dr.L. Waller), david.moats@helsinki.fi (Dr.D. Moats), emily.cox@smithschool.ox.ac.uk (Dr.E. Cox), rob.bellamy@manchester.ac.uk (Dr.R. Bellamy).

¹ Orcid ID: <https://orcid.org/0000-0001-8071-4908>

² Orcid ID: <https://orcid.org/0000-0001-9622-9915>

³ Orcid ID: <https://orcid.org/0000-0002-8169-3691>

⁴ Orcid ID: <https://orcid.org/0000-0001-9592-705X>

¹ This was a question posed in a deliberative workshop discussed in this paper. See below.

In a moment of concern about “generative AI” technologies – and large language models (LLMs)² specifically – introducing informational unruliness into public discourse,³ we propose that deliberative researchers may have much to gain from attending closely to the *questionable* qualities of their devices. While conspicuously questionable technologies like LLMs – particular chatbot applications which discursively respond to user questions, or “prompts”⁴; – often (like the magic mirror) disguise the authority of knowledge claims, we suggest that such unruliness could also draw attention to the inventive possibilities that devices can introduce into deliberative practice.

In this study we deployed ChatGPT, a large language model (LLM) application, within a research apparatus developed for the deliberative appraisal of technology (Bellamy and Lezaun, 2017). Informed by literature on devices of participation (Marres and Lezaun, 2011), we introduced ChatGPT into 8 deliberative workshops appraising three prospective methods for removing carbon dioxide from the atmosphere: peatland restoration, biomass crops and biochar.⁵ Participants were recruited on a topic-blind basis and were provided with expert-curated resources on carbon removal methods, which included texts, physical samples, images, video and PowerPoint presentations. After an introductory presentation on carbon removal, participants were invited to pose questions to ChatGPT. Later, in the final session of the workshop, we provided participants with the texts generated by ChatGPT and invited group discussion around their appraisals of the texts.

We first outline the case for studying devices of deliberation, examining what the turn to devices in sociology and STS can contribute to deliberative research. Specifically, we contrast devices that appear conspicuously *questionable* with those that appear more banal. We then report our deliberative research with ChatGPT examining, first, “instrumental engagements” with the device as a more-or-less banal information retrieval tool and, second, a series of occasions where the unruliness of ChatGPT was critically engaged. In concluding, we elaborate the notion of questionable devices and reflect on the way carbon removal has been “devised” as a field in want of informed deliberation.

2. Why a device-centred approach to deliberation?

This study takes place against the backdrop of a resurgence of interest in “deliberative democracy” (Lövbrand et al., 2011; Mouffe, 2005). Recent years have, for example, seen “citizens’ assemblies” emerge as a deliberative procedure embraced by both activists and officials (see discussion in Willis et al., 2022). In challenging prescriptive theories of deliberative democracy, critical approaches in STS, sociology and related fields have long sought to empirically redescribe and specify the political capacities of deliberative procedures and expertise (Laurent, 2011; Lezaun and Soneryd, 2007; Pallett, 2015). Building on these latter studies, we suggest a focus on devices could both further empiricise the critique of deliberative practice and recast deliberative appraisal methodologies as a focus for experiments in participation (Chilvers and Kearnes, 2015; Lezaun et al., 2016).

² LLMs are machine learning models trained on large textual datasets, often gathered from the open internet.

³ Public concerns over generative AI have surfaced various uncertainties about LLMs, including: their capacity to hallucinate plausible sounding facts, reproduce stereotypes and prejudices present in their training data (Bolukbasi et al., 2016), copyright infringement (Marcus and Southern, 2024) and the environmental costs of training models (Bender et al., 2021). Major LLMs like ChatGPT are often designed to mitigate such harms with the effect that generated content often appears deferential to users and “diplomatic” when talking about controversial topics.

⁴ LLMs are designed to produce texts through a process of trying to predict the most likely next word in a sentence, given the previous words, based on a “prompt” – a question or request from the user.

⁵ The development and central controversies of this field are discussed below. The term “carbon removal” and acronym CDR are used as short-hand.

Practice-focused criticism of deliberation has often focused on the ways that experts designing deliberative procedures “frame” public issues. It has long been observed that frames can restrict the scope for contestation and lend legitimacy to expert definitions of problems, risks and technological commitments (Stirling, 2008). Participants in deliberative procedures are often discursively framed as “naïve” citizens who are, in principle, competent to engage in discussing expert-defined policy issues (Irwin, 2006; Irwin and Michael, 2003). In such criticism, the construction and deployment of “frames” is typically considered to be under the control of expert communities. This has led to various methodological innovations in deliberative research, such as experimentation with framing conditions, involving, for example, competing analogies to characterise technologies (Cox et al., 2021). It has also mobilised various reflexive tactics, such as “unframing” (Bellamy and Lezaun, 2017), that explore the particular expertise and expert discourses being put to work and “open-up” their relations to publics. Tactics like this have also provoked questions about how discursive frames relate to practices of spatially organising and facilitating small-group deliberative set-ups (Bellamy et al., 2019). However, for the most part criticism of framing has tended to foreground procedures, institutions and discourses organising deliberation and focused less on materiality (see discussion in Davies, 2014).

Another line of practice-focused criticism has centred on socio-material approaches to deliberation. Here, the emphasis is on the roles that “things”, rather than procedures, play in the construction of deliberative assemblies (Latour, 2005).⁶ One prominent account is found in the concept of the “hybrid forum”, elaborated by Callon et al. (2009), which proposes that technological controversies can give rise to novel spaces of dialogic interaction. Despite the orientation of the hybrid forum to publics that emerge “in the wild”, the concept has been widely put to work (not least by Callon et al. themselves) in service of designing and evaluating procedures for secluded deliberation (Farías, 2016; Macnaghten, 2021). Strong oppositions between procedural and socio-material approaches to deliberation are therefore misleading, since the notion of “public deliberation” necessarily implies a material concern with publicity (see discussion in Whatmore and Landström, 2011). In a practical sense, such distinctions are better conceptualised as a spectrum of more-or-less experimental approaches to the material artifact of participation (Lezaun et al., 2016).

Attending to “devices”, we approach deliberation from a pragmatic stance rather than being guided by prescriptive theories that seek issue-resolution and consensus. Interest in “devices” has emerged alongside a renewed focus on materiality at the intersections of sociology and political theory (Marres and Lezaun, 2011). The concept of the device has now been subject to wide theoretical interrogation and it is not the aim of this paper to rehearse the various lines of elaboration (for an overview see Mcfall, 2014). Two key points from these debates are pertinent to the analysis presented here. First, a device is, in one sense, a kind of technology; something that affords its user a particular kind of instrumental power. In another sense, a device also refers to something contrived and worthy of a certain scepticism. Devices, then, are not simply tools – they often do something more than their designers and users acknowledge (Ruppert et al., 2013). Particularly in digital societies, devices can be seen to “format” participation (Kelty, 2020; Marres, 2012); investing things with participatory capacities is often an explicit objective of digital design.

In the study of marketing, McFall (2014) makes the case for attending to devices as inseparable from “devising” practices:

“devices are not just material, mechanical contraptions they are also, sometimes simultaneously, tricks, disguises and deceptions. Sometimes these

⁶ Latour’s account of the “Parliament of Things” represents one much discussed attempt to reconceive deliberative assemblies. It is notable that studies foregrounding materiality rarely use the term deliberation, which is often conflated with prescriptive theories of “deliberative democracy”.

backfire or don't fire at all and sometimes they work far better and in ways other than those originally anticipated. This combination of unruly and instrumental effects is ... what is in play and at work in the devising of markets" (24).

Unlike the conspicuous symbolism and messaging of advertising, it is precisely because most marketing devices appear banal, McFall argues, that they are so effective at attaching products to consumers. Insofar as they cloak the material artifice of deliberative practice, banal devices can therefore be seen to work against deliberative experimentation.

In contrast to banal devices, we propose the category of *questionable* devices as essential to experiments in deliberative participation. Questionable devices, we suggest, are not simply things that elicit requests for information or occasion expressions of curiosity or scepticism from questioning subjects. They are also questionable in the sense of appearing unruly, potentially provoking critique of the apparatus mediating and regulating discursive exchange. Distinctions between questionable and banal devices are not intrinsic but, we propose, emerge in the approach by which a deliberative apparatus is put into practice.

In elaborating the notion of *questionable* devices, debates about "idiots" and "idiocy" in the field of public engagement with science and technology (PES) are instructive (Michael, 2012).⁷ One study that is particularly pertinent here is the deployment of automated bots by Wilkie et al. (2015) to provoke engagement of Twitter users with energy-demand reduction. Their "idiot" text-generating bot, @Jimmy_gibbon, was designed to conspicuously subvert conventional discursive interaction. Despite this, @Jimmy_gibbon appeared surprisingly capable of eliciting responses and interaction from the platform's users. The study therefore makes clear how engagements with text-generating devices can be rendered obscure when reduced to their literal content. It is therefore an interesting comparison with our study, since, unlike Wilkie et al.'s bots, LLMs like ChatGPT are designed to avoid appearing idiotic; that is, they are designed to simulate plausible discursive interaction and generate text that appears intelligible.

In the context of deliberative research, we therefore propose to approach ChatGPT as an "idiot" in disguise: that is, as a device that, despite its convivial appearance, may introduce unruliness into deliberation. Our approach here notably diverges from deployments of LLMs in participatory procedures in the field of "AI" governance, where the emphasis is on the efficiencies they may introduce as plausible interlocutors.⁸ While social science uses of LLMs are still emerging (Cox et al., 2024), there are some precedents for embracing the unruliness of these devices as a potentially inventive resource for deliberation. Anthropologists have, for example, used LLMs to study social stereotypes (Caliskan et al., 2017). Others have begun reflexively experimenting with image-generating devices to explore dominant cultural imaginaries present online (de Seta et al., 2023). In this sense, generative AI tools could play not dissimilar roles to established techniques such as photo elicitation (Harper, 2002) or data visualization (Munk et al., 2019) in structuring deliberative inquiry. By introducing unruliness, we suggest that LLMs like ChatGPT may therefore not primarily test the critical capacities of deliberative subjects but rather the capacities of deliberative formats to experiment with such devices.

⁷ While idiot is today often a pejorative term, as taken up in PES the idiot is defined in terms closer to the classical notion of someone who refuses to take part political life (Lezaun and Soneryd, 2007).

⁸ Open AI, the developer of ChatGPT, recently funded experiments in soliciting democratic inputs to AI. While these initiatives aim to be technologically innovative, LLMs are deployed instrumentally to replace human moderation or automate qualitative analysis so that the participatory procedure can scale. See: <https://openai.com/blog/democratic-inputs-to-ai-grant-program-update> (accessed 24/05/2024)

3. Deliberating carbon removal with ChatGPT

Carbon dioxide removal is an emerging research field closely linked with climate science and recent political commitments to future "net zero" emissions targets. Current and ongoing research and development programmes into carbon removal have focused on setting expectations about technology deployment in industry and government. Against this backdrop, a variety of empirical social science has explored lay and stakeholder responses to scenarios, proposed methods, field trials and risks associated with future technology deployment, within which deliberative approaches appear relatively prominent (e.g. Low et al., 2024). In this work, deliberative methodologies have been used by researchers working in fields that include earth systems governance, social risk perceptions and critical political economy (see discussion in Waller et al., 2024). Despite such methodological diversity, attempts to organise carbon removal as a scientific field (as we show below) have positioned public deliberation primarily in relation to the "acceptance" of research and development. Experimental deliberative research is therefore not only a matter of methodological development but critical, we suggest, to contesting instrumental positionings of social science in the field of carbon removal.

Attempts to organise scientific inquiry on carbon removal have often defined carbon removal as a public good to be pursued through technological innovation. One prominent account is found in the *State of Carbon Removal* reports (Smith et al., 2023, 2024), which, structured around a linear innovation model, assesses the "gap" between political targets, current deployment and progress on innovation. Research on public perceptions plays an important role in these reports and is closely linked with communications strategies. Publics are defined primarily as potentially both an obstacle and resource for innovation: "publics are not simply a source of potential opposition; they also play a crucial enabling role, for instance as advocates or as market actors." (Smith et al., 2024: 105). Social science is positioned as aiding communication, with notable prominence given to the social media platform X (formerly Twitter), analysed as a site for collecting "non-elicited" responses and tracking public "attention"; analytic categories and metrics of platform economies standing-in for apparent shortcomings in academic social science (c.f. Waller and Chilvers, 2023). The reports make clear that a central contribution of scientific assessment is "improving the information landscape... informing and aiding the efforts of those who seek to develop CDR as part of successful climate action" (Smith et al., 2023: 99). While publics are not constructed as a "threat" to carbon removal in the way they have been in other fields of promissory technoscience, such as synthetic biology (Marris, 2015), we nonetheless find in these reports a field that appears *in want* of informed deliberation.

The study we report here involved introducing ChatGPT (version 3.5) into 4 day-long workshops in major cities around the UK (London, Cardiff, Edinburgh and Belfast) each split into 2 groups (i.e. 8 groups in total) appraising carbon removal methods. The 8 deliberative workshops we designed followed the same structure.⁹ The exercise with ChatGPT was broken down into two sections: first, a session where the groups were asked to formulate and agree a question about carbon removal to pose to ChatGPT (which we made clear could be "anything" they wished to ask) and, second, a session where the text generated in response to their chosen question was appraised and evaluated by the group (texts included in [Supplementary Materials](#)). These sessions took place at the beginning of the workshop and end of the workshop,

⁹ The workshops took place in four locations: London, Cardiff, Edinburgh and Belfast, with two workshops of ~8 participants in each. Participants were recruited using an agency to achieve a diversity of sociodemographic characteristics - age, gender, ethnicity, and political affiliation - in each group.

respectively.

The question formulation session took place immediately following introductory presentations about the topic of carbon removal.¹⁰ The session began with a short introduction to ChatGPT (PowerPoint slide included in Appendix). We then invited participants to, first, individually formulate questions and then collectively decide as a group on one question to pose. Since anything could be asked, moderators were agnostic about what would constitute a question and groups were required to reach a decision on their own terms. Due to time constraints, many groups simply voted on which individual question to choose, e.g. via straw polls, with some merging multiple questions together.

Following the question formulation session, the workshop proceeded with structured discussions of three land-based carbon removal methods being trialled and developed in a UK-based strategic research programme: peatland restoration, biomass crops and enhanced weathering. During this, participants were given a variety of stimulus materials including text, images, and objects which we used to encourage multi-sensory perspectives on the carbon removal methods being discussed. In taking this approach, the workshops sought to elicit perceptions of the methods and their risks (being analysed separately).

Finally, the workshop ended with the participants receiving a print-out of the ChatGPT response to their group’s question; they read the text individually and then discussed their responses as a group. They were asked about: (1) their *expectations* prior to reading the text and their first thought or feeling after reading it, (2) whether any *familiar topics* appeared in the text, with participants invited to relate them back to specific discussions that had taken place during the workshop, (3) whether there was anything in the text that hadn’t been discussed in the workshop so far (i.e. any *novel topics*), and (4) how they would formulate a follow-up question for ChatGPT. In facilitating the appraisal of these texts, the moderator’s guiding aim was to maximise discussion while remaining agnostic about its content. Moderators avoided acting as spokespersons for carbon removal or ChatGPT and did not cast judgements on anything participants said. If invited to play such roles, moderators turned the questions back to the group e.g. “is this an important question for anyone else? tell us why?”. The approach was therefore designed to, as far as possible, engender an experimental atmosphere in which the idiocy of deliberating carbon removal with ChatGPT could be submitted to collective critique.

4. ChatGPT as a questionable device?

In what follows, we first outline two broad patterns of “instrumental engagement” that developed during the exercise, in which ChatGPT was engaged as a banal device for deliberation, its potentially unruly capacities glossed over. We then outline a series of “questionable occasions” in which ChatGPT appeared a more unruly device for deliberation, with participants critically engaging with the deliberative apparatus. The instrumental engagements and questionable occasions were identified through a coding analysis of the workshop transcripts.¹¹

¹⁰ The presentations introduced carbon removal in one of two ways: a ‘techno-economic’ introduction centred around the quantitative net-zero emissions scenarios of national and international scientific authorities (4 workshops) or as an ‘everyday life’ introduction that invited participants to discuss the concept of net-zero in relation to changes in their local area (4 workshops). These contrasting introductions provided a ‘soft’ framing experiment for the workshop overall.

¹¹ Our coding approach was developed using NVIVO software. In the initial stage, one researcher undertook an open-coding exercise on all transcripts. All authors read the transcripts and commented on the coding frame. In this process we identified both the instrumental engagements and questionable occasions. While we make no strong claims about our inductive findings, the coding was conducted in a spirit of openness and loosely inspired by situational analysis (Clarke et al., 2022).

4.1. Instrumental engagements

4.1.1. Questioning as querying

During the question formulation session, critical discussion of ChatGPT predominantly focused around concerns about how to design effective queries for “information retrieval” (discussion in Rogers, 2013: 19–38). There appeared little resistance to our proposal to explore whether ChatGPT might enrich deliberation on carbon removal. Almost all participants had heard of ChatGPT and seven out of eight groups contained at least one active user of the device, notably in workplaces. Only a small minority of participants expressed explicit scepticism about the premise of posing ChatGPT questions about carbon removal (see below). Participants with experience using ChatGPT often offered advice to others on how to formulate a question that would return relevant and reliable information. Evident awareness of potential artistic uses of ChatGPT did not, for the most part, translate into the formulated questions (see Table 1) which represent a relatively narrow engagement with the generative capacities of the device. In short, the act of “questioning” here was predominantly expressed as a technical activity of “querying”.

The following interaction responding to the moderator’s introduction of ChatGPT appeared exceptional for directly challenging the use of the device:

Seamus: Can I just ask a question? You said it’s a commercial...so commercial means it’s led by a company?

Moderator: Yes.

Seamus: So if it’s a commercial entity and you say it doesn’t take sides, but it may be biased, is it biased in favour of the commercial...?

Moderator: I think the kind of response it will give you... [reverts to script] so when you ask it a question, the kind of response it will give you will be more like an interaction with customer service...

Seamus: So completely biased towards that customer that they’re representing?

Moderator: I think the designers of ChatGPT would say that they’re trying to make the tool as unbiased as they can.

Seamus: They would say that.

Ann: [Laughs].

[...]

Moderator: [...] I should point out that this is a free-to-use tool on the internet, so anyone here can use this tool. We’re using it for that reason. It’s just you can all go online and ask ChatGPT yourselves if you wanted to.

The participant’s success in engaging the moderator with their

Table 1
Questions for ChatGPT agreed by the 8 workshop groups.

Group	GPT Prompt
Cardiff 1	<i>What is the feasibility of carbon removal and over what timeframe?</i>
Cardiff 2	<i>Based on existing research, describe the proposed methods for carbon removal and for each method, describe advantages, disadvantages, costs and expected outcomes</i>
London 1	<i>What are the 10 best carbon removal methods in rank order?</i>
London 2	<i>What is the most economical way to remove carbon without creating more carbon that has been scientifically proven to be successful and what roles can individuals play?</i>
Belfast 1	<i>Explain to a 10 year old which country is leading on carbon removal research, development and implementation</i>
Belfast 2	<i>What are the pros and cons of carbon removal and where does it go?</i>
Edinburgh 1	<i>List top 5 methods for carbon removal from the atmosphere in terms of cost effectiveness, safety, sustainability and reusability, based on factual evidence.</i>
Edinburgh 2	<i>How can UK low-income families help to remove carbon?</i>

concerns about “bias”¹², provided a rare occasion where a moderator was drawn into a position of representing (what they took to be) the intentions of the device’s designers. This elicits a challenging retort and a laugh from another participant. The latter’s laughter may signify many things but, from the moderator’s perspective (one of the authors), it minimally indicated that some kind of transgression had occurred. The moderator subsequently restated the justification for using the tool, focusing on it being “free-to-use” and as accessible to “anyone”. The question formulation exercise then proceeds with no further direct challenge to the use of ChatGPT.

While direct challenges were the exception, the laughter elicited above might be situated in the context of other subtle expressions of dissatisfaction or concern that the introduction of ChatGPT surfaced, which can be detected throughout the transcripts. For example, we can detect various murmurs in the following example where the moderator sticks to their script about ChatGPT’s “matter of fact” response style:

Fred: What’s the most economical way to remove carbon without creating more carbon. What was the last bit that you said?

Lily: That has been scientifically proven to be successful.

Fred: That has been scientifically proven.

Lily: Because we want data. We want hard facts, don’t we? Because you’re [gesturing at the moderator] saying on here, yeah, matter of fact answers, it’s good at getting that information.

Moderator: It will give you a matter of fact response... if you ask a matter of fact question.

Lily: Because, I don’t know, I don’t want an open-ended answer, you see. I want to know what I can do now. I don’t know how everyone else feels about it, but it is a state of emergency so what... We’re all frustrated. We want to know what is it we’re doing or want to do and what has been proved, not just... Maybe we should say internationally, what has been proven internationally rather than just... I mean, or would it automatically pick up global responses, I don’t know.

In response to the moderator’s use of the phrase “matter of fact” – intended to refer to the presentational style of the device’s text responses – ChatGPT here becomes positioned as potential vehicle of scientific certainty. In rejecting “open-ended” answers, Lily’s speech also points to underlying antagonism – “it is a state of emergency” and “we’re all frustrated” – and they end exasperated: “I don’t know”(!). This could have raised some potentially challenging questions for the moderator about why they introduced ChatGPT rather than more data or facts, but the group avoided explicitly challenging the moderator and the discussion reverts to focus on the wording of question.

4.1.2. Literary style as information structure

Responses to the texts generated by ChatGPT often focused on their style and form. It was notable that all but one of the texts were presented in a list format of either bullet points or numbered entries (see [Supplementary Materials](#)), typically sandwiched between two paragraphs of prose.¹³ Many of the participants’ initial responses to the texts were qualified in relation to the list structure. Despite our introduction to ChatGPT emphasising its “diplomatic” style of response, the list-structured texts generated were appraised in almost all groups as representing a “summary”, “overview”, a “breakdown” or “synopsis” of the topic, or as “comprehensive”.¹⁴ A common sentiment, detectable

¹² Bias was a term that had been deliberately avoided due to its anti-sociological connotations.

¹³ Although two of the questions in [Table 1](#) explicitly invited a list response, in testing querying we found that list-style responses were also frequently returned.

¹⁴ One group appeared exceptional for almost unanimously appraising their list-structured text as “vague” and “lacking detail”.

throughout discussions, in all but one of the workshops, was that the lists represented a “starting point” for structuring further inquiry. In such cases, some participants suggested that ChatGPT could enable them to continue their own research independent of the deliberative process.

The following exchange can be seen to illustrate how in appraising the lists in the generated texts questions of literary style were often conflated with questions of information structuring:

Jack: I think as a research method, it’s actually quite effective in what you need. It definitely gives you a starter for ten, to then develop your understanding on each of these. You could easily then go on and break each five of them down and get even more information. I think it’s relatively reliable, given it states some sort of knowledge, which then you can, again, adapt on. So, yeah, I think it’s quite a useful tool.

Nathan: The answers are kind of, they’re factual, but they’re vague, at the same time.

[...]

Kiera: Yeah, I think that’s, pretty much, what I took away. It’s like, it’s a starter, it gives you somewhere to then build on, like, you would then go and search each of these things, maybe individually, to get more information.

All participants in this interaction respond, in different ways, to the style and format of the text. Despite the appearance of contrasting appraisals of the list style from Jack and Nathan, Kiera is able to present herself as agreeing with both, echoing Jack’s assertion that the list provides a structure from which the participants could now seek out “more information”.

However, criticism of the list style of the text could also be deployed more antagonistically to question the informational ontology of the texts generated. A particularly stark example emerged in one group where a participant gave short shrift to the list format of the text generated by ChatGPT.

Owen: Yes, just like what everyone said, really. It’s just a load of words to me, really. Just looking at it, I’m just, like, I don’t know what any of it means. So yes...

Moderator: What kind of expectations did you have before?

Owen: Just thought it might have given us some more of an answer instead of just spitting five things out at us, and just went you’ve got five chances, really, pick one, instead of saying, like, which one shall we go for? We could all read them and we could all have an argument which one we’re going to pick then. So...

[...]

Moderator: Owen, you were shaking your head?

Owen: Yes, it’s just, as I said earlier, it’s just words on a paper. If you can show me proper facts that they’re actually going to work, then I’ll be like, okay, I understand, but because it’s just words on paper and there’s five of them, I’m just like, well, which one actually works then?

This response was exceptional for the participants’ dismissal of the list format of text as conveying “just words” rather than “proper facts”; something they present as in line with wider sentiment in the group. It is not hard here to detect a critique of the deliberative model centred around the literate participant: “we could all read them and we could all have an argument...”. In this context, the figure of the information-seeking participant, positively articulated above, appears contrived and potentially divisive.

4.2. Questionable occasions: from unruliness to critique

We now turn to some examples where interactions with ChatGPT appeared to introduce unruliness into the deliberation. Although there were various potential examples that could have been drawn on, the

authors have chosen those where engagements with ChatGPT occasioned collective critique of the deliberative apparatus.

4.2.1. Confusing issue definitions

The topic of carbon removal introduced in the workshop had centred around definitions developed by scientific authorities, like the Intergovernmental Panel on Climate Change, that distinguish activities that remove carbon dioxide from the atmosphere from activities that reduce emissions of greenhouse gases. In practice, such definitions are far from straightforward and much recent controversy in climate policy has centred around distinguishing carbon removals from “offsets” and how the category of “residual emissions” in net zero scenarios is demarcated (Buck et al., 2023). Confusions between the categories of carbon removal and emissions reductions appeared particularly evident in relation to the ChatGPT response to the question: “How can UK low-income families help to remove carbon?”. Without exception, all of the activities it listed would be classified in mainstream climate policy as emissions reductions activities rather than as carbon removal (see text in [Supplementary Materials](#)). The discrepancy between official definitions of carbon removal and the account generated by ChatGPT here highlighted the ambiguity of the phrase “remove carbon” and the ease with which it might be conflated with activities aiming to reduce the production of greenhouse gas emissions.

The following excerpt from the transcript illustrates how participants made sense of ChatGPT’s confusion between carbon removal and emissions reductions:

Moderator: So in terms of your expectations about what the text was going to show, could you just maybe say what you were expecting?

Dani: ...it’s given most of what I was expecting in terms of, okay, it’s talking about car-pooling, public transportation, [pause] thrifty, buying clothes that are second-hand. But... the things I mentioned earlier, that they’ve added that don’t align with the question. That I have a problem with.

Moderator: Okay, great. Thank you.

Meera: Yes, I think there’s a difference between reducing and removing, really, isn’t there? ...So that’s not really covering what we were thinking of. We looked at all these methods which might remove it or decrease what we have already...

Moderator: What were your expectations...?

Meera: To get more ways than the three we looked at, for example, to remove already existing...like the carbon footprint that is already there, to decrease it, really.

Moderator: And how do you feel about the responses?

Meera: This is more like now, you know, when I go to the shop, what do I...how can I travel into town? What we have created already, all this output, is not really relating to this, I would say.

[...]

Jim: I agree with that... Water conservation, it’s a noble cause but it isn’t really aligned with removing carbon in general. So it’s almost locked a couple of things on it. If I’m being really picky as well, I would say it’s favoured the American spelling.

[General laughter]

The above exchange occurred early in the session and foregrounds the lack of “alignment” between the text and the preceding workshop discussions about carbon removal. Possible explanations for this confusion in the text begin to be explored, focusing on the failure of ChatGPT to interpret their question in the way it was intended. While the clear-cut distinction between carbon removal and emissions reduction was challenged at other times throughout the workshops, in this example it became the focus of sustained critical questioning by the

participants.

4.2.2. Disaffection with expert precaution

With one exception, all texts generated by ChatGPT introduced new carbon removal methods and technologies into the workshop discussions. Moreover, there was a marked absence in the texts of any reference to the three methods that the groups had spent the previous hours discussing. In the engaging with ChatGPT’s texts, the moderators asked participants whether there was “anything familiar” in the text that could be related back to earlier workshop discussions. This led to various comparisons between ChatGPT’s texts and the expert-curated resources, highlighting (if it had not already been raised) the widespread absence of reference in the ChatGPT texts to the three methods addressed in the workshop.

The following exchange illustrates the dramatic contrast some participants drew between the view of carbon removal in ChatGPT’s texts and that of the prior workshop discussions.

Moderator: Anyone else this side of the room, was there anything on this that you weren’t aware of?...

Anja: There’s certainly a whole new language, as well as terminology and methods of doing things. Some of these I have, kind of, heard of several things going on in the ocean beds and stuff, but a whole load of these... I mean, direct air capture, I’d never heard of that before. And the way that AI has put it is quite exciting really, you know. I find it fascinating.

Moderator: Has it changed the way that you feel about carbon removal?

Anja: It has a lot actually. I’m a lot more positive reading this. These ones [the carbon removal methods considered in the previous discussions] they’re just a little bit wishy-washy. And I think I, kind of, honed in on the fact that they weren’t, you know, solid and they haven’t got solid results. But this is a little bit more, kind of, the way it’s written is a bit more positive and intriguing really, and exciting to read.

[...]

Moderator: Did anyone else have any, kind of, particular emotions come up when you were reading this? Like excitement?

Rory: Well, it was a lot more positive that we read through earlier, because this was words like, you know, considered, promising and actively researched and implemented. And you look at these ones and it says things like poorly understood and all sorts, so they were all negative things like slow, difficult to process. I just felt the wording felt a bit more positive and a bit more cheerful than what we did earlier today.

For the first participant the text presents a radically different view of carbon removal to that developed in the preceding discussions; it is literally a “whole new language” that they find “exciting to read”. It may be tempting to infer from this that the participant has been captured by a particular “solutionist” version of carbon removal that abound on digital platforms (see [Waller and Chilvers, 2023](#)). Regardless, for our purposes, more interesting is the contrast the participant sets up with the methods discussed in the preceding hours of the workshop, which they characterise as “wishy-washy” and lacking “solid results”. Here the ChatGPT text provides a foil against which the participant reflects on the precautionary tone of the expert-curated resources, which generated not only questions but also “negative” affective responses, or disaffection.

4.2.3. Surfacing latent paternalism

During the workshop discussions, participants occasionally made use of their phones to source information. When this happened, moderators invited the particular participant to elaborate what they considered to be its contribution. In the below exchange, a participant compares the ChatGPT text against the response of a competitor text-generating LLM. The question the group had posed was: “Explain to a 10 year old which country is leading on carbon removal research, development and implementation”. The groups was dissatisfied with the text generated by

ChatGPT which, amongst other things, was widely mocked for underestimating a 10 year-old child's capacity to understand the concept (text in [Supplementary Materials](#)). During the discussion a participant queried Snapchat's "My AI" with the same question which they then present to the group:

Louise: Well, the Snapchat AI answers the question, because I asked it.

Moderator: Oh, interesting, go on, what does it say?

[...]

Louise: It says, "Hmm, explaining carbon removal and development and implementation to a ten year old can be a bit tricky, but let's give it a shot. Right now, many countries are working together to reduce carbon emissions and protect the environment. Some countries leading in this area are the United States, China and Germany who are working hard to find ways to remove carbon from the atmosphere and develop clean energy sources. It's like a big team effort to make our planet healthier." And then there's a little bit underneath that says, can you tell me more about carbon removal methods?

[...]

Grace: It's a similar answer to this one.

Louise: It [ChatGPT] did answer the question.

[Laughter]

From certain perspectives, this use of Snapchat AI might be seen as illustrating the critical capacity of the information-seeking participant to discriminate between sources and locate answers: not only can they do this independently of the experts, their approach appears demonstrably more effective since (in the participant's view at least) it "answers the question". But, as the subsequent laughter suggests, there also appear divergent views on what it means to "answer the question"; another participant asserts that ChatGPT's text is also an "answer". The interaction here suggests not only differing appraisals of the texts. By implication, the laughter also indicates a certain reflexivity about the querying mindset (discussed above) in which questioning becomes a narrow technical act of information retrieval. By invoking the 10 year-old as a figure to be addressed and making fun of ChatGPT's response the group surfaced, and playfully subverted, a paternalist dynamic that may have been latent in the deliberative apparatus.

4.2.4. Problematising social classifications

One question posed to ChatGPT was notable for inclusion of a social classification: the "low-income" family (see above, text in [Supplementary Materials](#)). The question was proposed by a participant, who raised concerns relating to low-income families throughout the workshop and consistently advocated the view that: "we're never going to tackle this until we tackle poverty first". But the text did not straightforwardly establish the priority of addressing poverty for evaluating carbon removal as socially just (or not). Instead, it appeared to introduce disagreements into the group over the definition of categories like "low-income", why the family was the privileged social unit, as well as how the experiences of disadvantaged groups can be authentically represented.

The text generated by ChatGPT proscribed a list of practical measures that could be followed by low-income families. In their initial responses to the text several participants indicated that they were "impressed" with how practical the measures outlined were. However, another participant took issue with these appraisals:

Dani: I'm disagreeing with the fact that it's good, because we've used the term low-income families and there's a number of things to me that do not scream low income. So, for example, I know it says, if possible, invest in a fuel-efficient or electric vehicle ... the two do not correlate ... [or] participate in local environment groups and community projects focused on carbon reduction. If I'm focused on trying to get a cleaning job, for

example, what time do I have to add to that? [...] I'd probably go back to ChatGPT and say: some of these things are not applicable to low-income families. Can you basically redo it?

Dani's critique here is presented from multiple perspectives, sometimes using the first person and at other times referring in a more distanced way to the category of the low-income family. Such referential ambiguities here potentially raise questions about how the social classifications mobilised in the deliberation interact with participants' lived experiences. While representations of low-income families in the text were appraised in different ways, we see here how the engagement with ChatGPT enabled the participants to problematise the way social classification operates in the field of carbon removal. In doing so, the group drew attention to the remoteness of policy debates on carbon removal from the material concerns of everyday social life.

5. Discussion and conclusions

Despite being a focus of prominent concerns over "AI", in our deliberative study ChatGPT was only occasionally engaged with (explicitly at least) as a questionable device; its capacity to potentially generate garbled texts or misinform deliberation appeared untroubling to many participants, with some notable exceptions ("questionable occasions") discussed above. Our deployment of ChatGPT therefore did not, for the most part, appear to engender the kinds of reflexivity about how participation is structured and formatted, that has often characterised processes of public formation in digital societies.

The analysis above has pointed towards two broad patterns of interaction in which ChatGPT performed as a banal device for deliberation, which we have termed "instrumental engagements". First, the task of questioning the device about carbon removal was often engaged with as a technical practice of querying for information retrieval. Second, many of the texts were presented in list form, with participants often appraising the lists as an information structure (e.g. as presenting an "overview") rather than as a literary style. In these instrumental engagements, ChatGPT was treated as a tool that could straightforwardly inform deliberation on carbon removal. In engaging ChatGPT as an authoritative source and synthesiser of information, instrumental engagements did not simply stymie more inventive possibilities for deliberative participation with generative tools. Instrumental engagements also erased critical distinctions between the information infrastructures of the digital economy and those of technoscience. Despite proliferating informational unruliness – instrumental engagements with ChatGPT being radically agnostic about sources of authority on carbon removal –, such engagements enacted the small-group in much the same way that an expert presentation or panel might: as a naïve collective becoming informed. Even as it appeared to undermine the public authority of science – treating digital publicity as analogous with (even substitutable for) scientific knowledge claims –, ChatGPT could constructively participate in the performance of small-group deliberation on carbon removal.

In drawing attention to the artifice of the deliberative apparatus, the more *questionable* occasions – i.e. those interactions that made explicit the unruliness ChatGPT introduced into the deliberation – did not simply disrupt the deliberation. When engagements with ChatGPT appeared to make explicit its informational unruliness it also often bought into view more banal devices organising deliberative participation: issue definitions, expert-curated resources, lay identities and social classifications. How such devices stabilise framings of a field in want of informed deliberation, and position small-group procedures as stepping in to fill the deficit, could here be submitted for collective critique. In the questionable occasions, we saw glimpses of how banal devices could not only organise deliberative participation but also alienate (on engagement and alienation see [Marris, 2015](#)): by framing-out conceptual ambiguity, engendering affective disengagement, infantilising lay identities, and misrepresenting social groups. In drawing attention to

dynamics of alienation, such engagements did not simply reveal ‘hidden’ structures organising deliberation e.g. public deliberation providing cover for technocratic order. Bringing specific actors alienated from the field – such as “low-income” groups or users of social media platforms like Snapchat – into the foreground of the discussions, provoked questioning about the roles played by social inequalities and digital media in framing the field of carbon removal as in want of informed deliberation. Deliberation here could be recast (if only fleetingly) as a format for experimenting with the devices of public engagement with carbon removal.

The distinctive contribution of device-centred approach can be specified further by situating this study alongside one in which scenarios were deployed as instruments of deliberation. In a stakeholder deliberation addressing the potential for carbon removal to delay action to mitigate climate change, McLaren et al. (2021) deployed a series of explicitly “political” scenarios. Situated in relation to the political economy of climate change (see also Markusson et al., 2022), the scenarios were deployed in workshops with the aim of exposing strategies and mechanisms of “mitigation deterrence” for collective engagement. McLaren et al. (2021) make clear that the scenarios were instruments not just for discursive exchange between individuals but also the formation of collective discourses about mitigation deterrence. A key focus of the study was on how concerns about mitigation deterrence can be deflected, with refusals to engage with the scenarios explained by reference to the participants’ positioning as stakeholders. There may be tactical justifications for reducing idiotic engagements with the scenarios to matters of “deflection”, since permitting idiocy would compromise the priority of political economy to define what is political about these scenarios. Nonetheless, this move also makes clear that, in this set-up, the scenarios could only perform as instruments for deliberating mitigation deterrence; experimentation could not extend to idiotic engagements that might destabilise the framing of the workshop as a format of stakeholder deliberation.

In proposing closer attention to the questionable, or unruly, character of devices, the paper therefore aims to problematise not just digital

novelties but also bring into view the roles seemingly more banal devices play in deliberative participation. In emerging fields of technoscience, devices like scenarios often play a critical role in organising interactions between science and politics. If fields like carbon removal are in want of informed deliberation, we suggest this may have less to do with the accuracy and accessibility of information and more to do with the (narrow range of) devices organising the spheres where promising technologies can be legitimately contested.

CRediT authorship contribution statement

Laurie Waller: Conceptualization; Methodology; Investigation; Formal analysis; Writing - Original Draft; **David Moats:** Conceptualization; Investigation; Writing - Original Draft; **Emily Cox:** Methodology; Investigation; Writing - Review & Editing; **Rob Bellamy:** Methodology; Investigation; Writing - Review & Editing; Funding acquisition.

Funding

The authors gratefully acknowledge research funding from the Natural Research Environment Council for the project: “The UK GGR Directorate Hub.” Grant number: NE/V013106/1.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The paper has benefited from discussions with James Palmer, Manon Burbidge and Shilpa Sanjeevan who advised on and supported the delivery of the deliberative workshops.

Appendix 1. Introduction to ChatGPT

Below is the slide shown to participants outlining the task of questioning ChatGPT. We offered participants three considerations to think about when formulating a question or prompt.

Asking Chat-GPT about carbon removal

Decide as a group on one question to ask Chat-GPT

Later today, we’ll ask it your question, print the response, and share and discuss

Three considerations:

1. Ask for **discreet factual answers** and you will probably get them.
2. AI tools often try to **avoid taking sides**.
3. What AI tools present as **credible** information may sometimes just be what’s **popular** on the internet.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2024.103940](https://doi.org/10.1016/j.envsci.2024.103940).

Data availability

The data that has been used is confidential.

References

- Bellamy, R., Lezaun, J., 2017. Crafting a public for geoengineering. *Public Underst. Sci.* 26 (4), 402–417.
- Bellamy, R., Lezaun, J., Palmer, J., 2019. Perceptions of bioenergy with carbon capture and storage in different policy scenarios. *Nat. Commun.* 10 (1), 743.
- Bender, E.M., Gebru, T., McMillan-Major, A., & Shmitchell, S. (2021). On the Dangers of Stochastic Parrots: Can Language Models Be Too Big? *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency*, 610–623.
- Bolukbasi, T., Chang, K.-W., Zou, J.Y., Saligrama, V., Kalai, A.T., 2016. Man is to computer programmer as woman is to homemaker? Debiasing word embeddings. In: Lee, D.D., Sugiyama, M., Luxburg, U.V., Guyon, I., Garnett, R. (Eds.), *Advances in Neural Information Processing Systems* 29. Curran Associates, Inc, pp. 4349–4357.
- Buck, H.J., Carton, W., Lund, J.F., et al., 2023. Why residual emissions matter right now. *Nat. Clim. Change* 13 (4), 351–358.
- Caliskan, A., Bryson, J.J., Narayanan, A., 2017. Semantics derived automatically from language corpora contain human-like biases. *Science* 356 (6334), 183–186.
- Callon, M., Lascoumes, P., Barthe, Y., 2009. *Acting in an uncertain world: An essay on technical democracy*. MIT Press.
- Chilvers, J., Kearnes, M., 2015. *Remaking participation: Science, environment and emergent publics*. Routledge.
- Clarke, A.E., Washburn, R., Frieze, C., 2022. *Situational analysis in practice: mapping relationalities across disciplines*. Routledge.
- Cox, E., Pidgeon, N., Spence, E., 2021. But they told us it was safe! carbon dioxide removal, fracking, and ripple effects in risk perceptions. *Risk Anal.* 42 (7), 1472–1487.
- Cox, E., Shirani, F., Rouse, P., 2024. Voices from the algorithm: large language models in social research. *Energy Res. Soc. Sci.* 113, 103559.
- Davies, S.R., 2014. Knowing and loving: public engagement beyond discourse. *Sci. Technol. Stud.* 27 (3), 90–110, 3.
- Farias, I., 2016. Devising hybrid forums: Technical democracy in a dangerous world. *City* 20 (4), 549–562.
- Harper, D., 2002. Talking about pictures: A case for photo elicitation. *Vis. Stud.* 17 (1), 13–26.
- Irwin, A., 2006. The politics of talk: Coming to terms with the ‘New’ scientific governance. *Soc. Stud. Sci.* 36 (2), 299–320.
- Irwin, A., Michael, M., 2003. *Science, Social Theory & Public Knowledge*. McGraw-Hill Education, UK.
- Kelty, C.M., 2020. *The participant: A century of participation in four stories*. University of Chicago Press, Chicago, IL (accessed 5 April 2023).
- Latour, B., 2005. From Realpolitik to Dingpolitik. In: Latour, B., Weibel, P. (Eds.), *Making Things Public: Atmospheres of Democracy*. MIT Press, London, pp. 14–41.
- Laurent, B., 2011. Technologies of democracy: experiments and demonstrations. *Sci. Eng. Ethics* 17 (4), 649–666.
- Lezaun, J., Marres, N., Tironi, M., 2016. Experiments in Participation. In: Felt, U., Fouché, R., Miller, C.A., Smith-Doerr, L. (Eds.), *The Handbook of Science and Technology Studies*. MIT Press, pp. 195–219.
- Lezaun, J., Soneryd, L., 2007. Consulting citizens: technologies of elicitation and the mobility of publics. *Public Underst. Sci.* 16 (3), 279–297.
- Lövbrand, E., Pielke, R., Beck, S., 2011. A democracy paradox in studies of science and technology. *Sci. Technol. Hum. Values* 36 (4), 474–496.
- Low, S., Fritz, L., Baum, C.M., et al., 2024. Public perceptions on carbon removal from focus groups in 22 countries. *Nat. Commun.* 15 (1), 2060.
- Macnaghten, P., 2021. Towards an anticipatory public engagement methodology: deliberative experiments in the assembly of possible worlds using focus groups. *Qual. Res.* 21 (1), 3–19.
- Marcus, G., & Southen, R. (2024, January 6). *Generative AI Has a Visual Plagiarism Problem*. *IEEE Spectrum*. <https://spectrum.ieee.org/midjourney-copyright>.
- Markusson, N., McLaren, D., Szerszynski, B., et al., 2022. Life in the hole: practices and emotions in the cultural political economy of mitigation deterrence. *Eur. J. Futures Res.* 10 (1), 2.
- Marres, N., 2012. *Material participation: Technology, the environment and everyday publics*. Palgrave Macmillan.
- Marres, N., Lezaun, J., 2011. Materials and devices of the public: an introduction. *Econ. Soc.* 40 (4), 489–509.
- Marris, C., 2015. The construction of imaginaries of the public as a threat to synthetic biology. *Sci. Cult.* 24, 83–98.
- Mcfall, L., 2014. *Devising consumption: Cultural economies of insurance, credit and spending*. Routledge.
- McLaren, D., Willis, R., Szerszynski, B., et al., 2021. Attractions of delay: Using deliberative engagement to investigate the political and strategic impacts of greenhouse gas removal technologies. *Environ. Plan. E: Nat. Space* 61 (1), 578–599.
- Michael, M., 2012. What Are We Busy Doing?: Engaging the Idiot. *Sci., Technol., Hum. Values* 37 (5), 528–554.
- Mouffe, C., 2005. *On the Political*. Routledge.
- Munk, A.K., Madsen, A.K., Jacomy, M., 2019. Thinking through the databody: sprints as experimental situations. In: Mäkitalo, A., Nicewonger, T.E., Elam, M. (Eds.), *Designs for Experimentation and Inquiry: Approaching Learning and Knowing in Digital Transformation*. Routledge, pp. 110–128.
- Pallett, H., 2015. Public participation organizations and open policy: A constitutional moment for British Democracy? *Sci. Commun.* 37 (6), 769–794.
- Rogers, R., 2013. *Digital Methods*. MIT Press.
- Ruppert, E., Law, J., Savage, M., 2013. Reassembling social science methods: the challenge of digital devices. *Theory, Cult. Soc.* 30 (4), 22–46.
- de Seta G., Pohjonen M. and Knuutila A. (2023) Synthetic ethnography: Field devices for the qualitative study of generative models. SocArXiv. Epub ahead of print 2023.
- Smith S.M., Geden O., Nemet G.F., et al. (eds) (2023) *The State of Carbon Dioxide Removal - 1st Edition*. The State of Carbon Dioxide Removal. Available at: (<https://www.stateofcdr.org/>).
- Smith S.M., Geden O., Schenuit F., et al. (eds) (2024) *The State of Carbon Dioxide Removal - 2nd Edition*. OSF. Available at: (<https://www.stateofcdr.org/>) (accessed 7 August 2024).
- Stirling, A., 2008. “Opening Up” and “Closing Down”: power, participation, and pluralism in the social appraisal of technology. *Sci., Technol., Hum. Values* 33 (2), 262–294.
- Waller, L., Chilvers, J., 2023. Climate change assessments, publics and digital traces of controversy: an experiment in mapping issues with carbon dioxide removal researchers. *Sci. Technol. Stud.* 36 (1), 2–23, 1.
- Waller, L., Cox, E., Bellamy, R., 2024. Carbon removal demonstrations and problems of public perception. *WIREs Clim. Change* 15 (1), e857.
- Waller, L., Rayner, T., Chilvers, J., et al., 2020. Contested framings of greenhouse gas removal and its feasibility: social and political dimensions. *WIREs Clim. Change* 11 (4), e649.
- Whatmore, S.J., Landström, C., 2011. Flood apprentices: an exercise in making things public. *Econ. Soc.* 40 (4), 582–610.
- Wilkie, A., Michael, M., Plummer-Fernandez, M., 2015. Speculative method and twitter: bots, energy and three conceptual characters. *Sociol. Rev.* 63 (1), 79–101.
- Willis, R., Curato, N., Smith, G., 2022. Deliberative democracy and the climate crisis. *WIREs Clim. Change* 13 (2), e759.
- Wynne, B., 2016. Ghosts of the Machine: Publics, Meanings and Social Science in a Time of Expert Dogma and Denial. In: Chilvers, J., Kearnes, M. (Eds.), *Remaking Participation: Science, Environment and Emergent Publics*. Routledge, pp. 99–120.